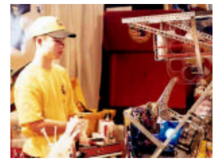

Best Practice

Science and Technology: Applications for Science and Engineering

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Goal and Objectives:

Science and Technology (SciTech) was written with several goals. The course is hands-on science and engineering, which will prepare students to perform in industry and university work environments with industry level evaluation. The course requires students to use high levels of thinking. To create a class management system that requires students to develop self-reliance and strong professional ethics, the course design mandates group interactions in thought, written word and physical performance of models. The course engages students in meaningful group, peer, and self-evaluation. The activities develop a system where students experience the joy of true authorship of ideas that only comes from making one's own ideas work in the real world. Within our community of students, teacher, industry and the Austin community at-large, the structure creates and fosters interaction with engineering in a long term and meaningful way. The course imparts a useful set of content skills and process skills preparing students for applications in physics, engineering, and design.

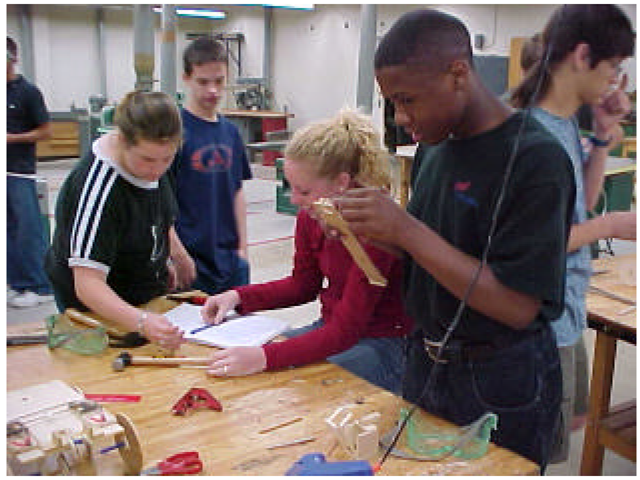
To accomplish our goals we visited several schools, held interviews with engineering representatives from firms in our community, and interviewed post-secondary science and engineering professors before settling on our current curricula. Surveying the traditional approach to science and engineering curricula, we decided the traditional model sequence had to be reversed. Traditionally, terms were memorized, concepts explained through a teacher-centered or book-centered delivery system and applications are rarely approached in any effectual way. Students never apply the learning to create products to prove they have command of the material. Students rarely produce products that would be of high quality and withstand industry level evaluation. We decided to flip the traditional model. Instead of terms-concepts-application, the course starts with an application. Conceptual understanding comes due to the parameters of the application and terms follow naturally. Our "constructivist" view of curricula establishes that concepts are built in the context of a complex application. In the traditional sequence, information is delivered in a thinking pattern of storage only and not retrieval for application. By having an application drive the information acquisition, the pattern for retrieval is established from the onset of thinking. This establishes that evaluation of an individual's learning achievement is based on what they can produce with the new ideas; * not on the amount of information they can store through memorizing. Producing products of agreed-upon quality with the new ideas is the core of evaluation. Without a change in the evaluation method, no course is different from the traditional method of content delivery.

Course Sequence:

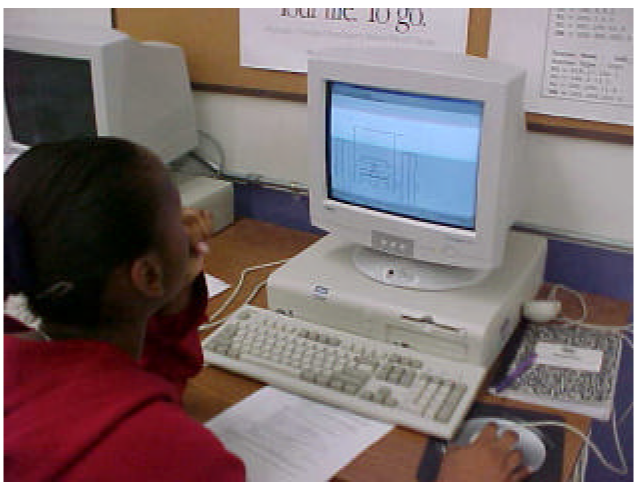
At the beginning of each semester (the course is an accelerate block course; that is, we teach it for two consecutive periods during our 7 period day and one semester equals a year of curricula), we develop a mechanical engineering challenge that the students will have to complete. The course is based in general design process on a "four step" design process: conceptualization, design, layout/construction, and evaluation. The actual time and performance sequence for the course is in tabular form below:

Weeks	Intermediate Goal Sequence	Performance Objectives
1-3	Skills Development	Computer Skills: WP, Spreadsheet, Network Management, CADD Content: Measurement, Vectors, Speed, Acceleration, Force, Newton's Laws, Work, Energy, Power, Graphical Analysis Drawing Skill: Perspective, Proportion, Scale, 3-veiw Orthographic Projection
4	Kick Off to ICP	Project Description, Course Measurement, ICP development, ICP Evaluation
5	ICP to GCP	Students Placed in final Groups, ICP Evaluation, GCP Development, Teacher Evaluates GCP
6-9	FDR to Engineer Presentation	FDR writing: Design Evolution, Mathematic Support (including Ramp Lab, MT Energy Lab, Function Spreadsheets), CADD (including: Course CADD, Full Drawing, and Individual. Parts drawings), Bill of Materials (aka BOM for cost analysis), Setup and Operation Instruction in 2 languages. Engineer Oral Presentation Development: Prepare a 10-15 min presentation on the contents of FDR in Power point or other appropriate presentation media
9	Engineer Presentation	Engineers spend 30 minutes with each group and evaluate the groups idea for feasibility with Engineer Evaluation Form and evaluate oral presentation effectiveness using Oral Presentation Rubric
10-11	Layout, Safety, and Tool Orientation	Orientation to technology area, material characteristics, Layout tools (Measurement, squares, etc), tool safety (we have both industrial floor machines and hand tools), Tool use performance(each student is given a personal performance evaluation), culminating in a safety test.
12-15	Prototype construction, testing, and design evolution documentation	Layout and Construction of Prototype Prototype Testing: Bench Tests and Course Tests Working Prototype
15-17	Final Device construction, testing, and design evolution documentation	Layout and Construction of Final Devices (3 Final Devices) Prototype Testing: Bench Tests and Course Tests Final Tests on Final Device with Statistical Analysis
18	Final Report (FR)	Complete FR

Project Description:



The ideas for the challenge are new every course cycle. We solicit ideas from former students, professional engineers, and our teaching staff. The challenge begins on "Kick-off" day when the challenge description and its design parameters are described to the students. The students then develop individual conceptual plans (ICP). The ICP's are the individual students' solution written in their individual logbooks. The ICP's are reviewed with the teacher where the teacher evaluates the idea for it's completeness and legality according to the parameters. The students are placed in groups of 3 (with some groups of 2 permitted, but no groups of 4 or higher) where they share the ICP's with each other. The groups develop a group conceptual plan (GCP) after evaluating the 3 ICP's brought to the group. The GCP is submitted to the teacher, who evaluates whether the plan meets the parameters of the challenge. It is important to note that the teacher interactions is purely as referee of the rules and intent of the challenge and in no way does the teacher add conceptual ideas from the teachers experience. The solution ideas must come from the group. The group of students writes a design plan that includes: design evolution, mathematical models of function, three view orthographically projected CADD drawing, Bill of Materials verifying the cost of materials, and setup and operation instructions in english and second language.



The contents of design plan are written in to the Final Design Report (FDR). The content of the FDR's are presented in an oral presentation to a visiting board of professional engineers from the engineering community of Austin. We contact them through email and they volunteer for three days of student design presentations at our school. Each group's design is evaluated for design feasibility by the engineers Sample questions from the SciTech design evaluation form use a scoring scale of: 5 for excellent, 4 for good, 3 needs some improvement, 2 needs much improvement, 1 not acceptable. Three sample questions of the eight questions on the form follow: 1. How likely is the design to perform the assigned task? 2. How easy is this device to manufacture? 3. How clear, complete, and accurate is the device drawings? Space is provided on the form for comments after each question.

Using the information developed from the engineer critique, the students modify the FDR for teacher approval to build the prototype. Before building the prototype for testing, the students go through safety. The prototype is bench and course tested until it works (see jpegs of students at work). Once the prototype works, three final devices are built. Each final device is course tested for consistency of function using time of function and consistency of results for data. The data is analyzed using Student T-test statistics to determine the statistical confidence they have in the consistency of function each of the final devices. The statistical confidence in the consistency of performance of the devices is equated with the quality of the design idea rendered by the group. The evaluation is based on the duration of performance not just on one single test. The evaluation is based on the comparison of more than one device's function again proving the validity of the design idea. All documentation culminates in the groups Final Report (FR).

Brief Lesson Plan:

The general teaching style we employ requires student responsibility and student concentration on the evaluation parameters prior to design and can be illustrated through a lesson plan description. The "Kick-Off" lesson plan includes the basic elements of our course. At the time for the Kick-Off, the students have been developing conceptual, computer, and physical skills in the initial skill development section of the course leading to the "Kick-Off". They are aware that success in the course is based on successfully completing a design that can perform the physical challenge consistently. We discuss the term success before we kick-off. Basically, there are two kinds of success in SciTech; Grade success and successful performance. If the device works, that is pure performance success. But, documentation of the idea and the evolution of the idea's development is an important part of the grade success. One of our standard mottoes reads, "If it is not written down, it never happened!" This means that if the device works and you never wrote down one item about the development and who's idea it was, as far as this class goes, it never happened! Documentation is as important if not more important that the device working. Conversely, if the device never worked but the idea development is documented perfectly you might have some grade success without the pure excitement of seeing one of your ideas work in the real world. And we as teachers have experience that indicates if you could make an A in the course without the device working, you will have great disappointment.

Leading up to kick-off, students and teachers in the building have a high interest in the new challenge. Former students ask our current students casually, "What is the challenge this semester?" Or later after kick-off, torturing them with, "my challenge was harder than yours", or equally terrorizing, "Man, yours is the hardest I have ever seen!" The exact challenge parameters and the course itself is the "best kept" secret at our school until the Kick-off. We hand out a kick-off sheet (displayed below) on the same day in all classes for that semester.

Spring 2002 SciTech
Mechanical Engineering Project

Welcome to the Science Academy SciTech course Mechanical Engineering project for Spring 2002. The following requirements must be met to successfully complete the course.

Course Diagram

The actual course will be on display in Room 11 Metal Shop. You will have to measure and record dimension of the course in your logbook upon seeing the course for the first time. And, we will give three subsequent days to visit the course and measure the course on a need basis. That is, if you did not get a measurement you needed on day one you revisit for the next three days only.

Object

Each team will design a device that does not exceed 6" in height and whose footprint does not exceed 144 sq. in. (footprint is the total surface area covered by the device in its starting position). No part of the device, in set and ready position, may exceed the 6" height and no part of the device may be outside to the designated starting area (or outside the airspace above the starting area). The device must be designed to operate from one of the two starting areas. The starting area choice occurs in design. From the designated starting area the device must be able to deliver the ball to any of the three target hoops. The target hoop for each run will be determined on each run by the throw of a dice. Once triggered, the device will retrieve the ball from its starting position and deliver it to and through the designated hoop. The ball must pass completely through the hoop and be released through the hoop to be successful. On the succeeding runs, the device must be adjustable to go to the next designated target hoop in less than min. So, finish a run, roll the dice, adjust the device to the next target (in less than a minute), and trigger the device and repeat. One device, only, can be built. The device will work from one starting area and deliver the ball to each of the hoops on command of a dice roll with the adjustment period between targets of 1 minute or less. Air space above the track is limited to the ceiling and ceiling fixtures in the room above the track. The device or the ball cannot touch any object that is not part of the device itself or part of the track.

Building Requirements

The device must be powered by the elastic potential energy of 2 mousetrap (you may use less than the energy in one mousetrap). The cost of the materials in one finished device must cost under $5.00 (fair market value including the cost of mousetrap). The device must be triggered by the finger print pad of one finger (triggered only--no input energy supplied by the finger when triggering). The overall size of the device must not be over 6" high and must have a footprint of 144 square inch before triggering after triggering the device may change size in the legal operation of the device.

Other Requirements

The written final design report will include (but limited to) operating instructions in two languages, bill of materials, assembly instructions (if assembly required before operation), fully developed CADD drawing of finished device and any other supporting documentation (lab reports, design analysis, math models, design evolution chronology etc.).

Evaluation

The device will be evaluated on the consistent and uniform delivery of the playing ball to the target hoop. The evaluation will be based on success rate and the time of function. The consistency of the delivery time and success rate for the final devices will be evaluated based on the average and standard deviation of function time. The standard deviation of the success rate and the time of function is compared for the three final devices, the lower the standard deviation, the better.

The Kick-Off content describes the intricate evaluation standards and describes the physical environment of the challenge. Students begin to formulate ideas and write them down in their logbooks even as the description begins to take form in their minds. We answer questions of "legality"(specifications), and purpose. The students create various other ideas that spring from students who think critically. The students formulate new concepts and develop an incessant need for numbers associated with the physical environment of the challenge. They need real numbers. We show them the course and they find measurement tools of all kinds on the course at the first viewing.

They sketch three view drawings of the course in their logbooks and begin to measure. They find a need for a consistent measurement system for discussion purposes. They decide on a measurement system to accurately discuss measurements being * taken. We tell them to measure every aspect of the course and record, for this is the only day they will be allowed to measure until after the design phase. We collectively attack the course, communicate findings, we think out loud. The only requirement is to be successful in completing the daunting, complex task. We don't compete against each other because we don't have to; the course is the only challenge. To make an idea work is the only competitor.

Work Performed by Students:

The need to succeed causes the need for concepts and terms. Concepts enter naturally, not through teacher-centered lectures taken out of context of the application. Students begin to ask for and receive concept lectures. These lectures occur with no teacher mandated sequence, in a discovery sort of way. The Kick-Off day mixes excitement, apprehension, critical thinking, physical performance, evaluation standards, and traditional concepts into a comprehensible plan for performance. Bright students, motivated, skilled, independent, self-reliant, and active, preparing for success.

Student focus and work planning leads the student groups to write several components of written reports required in the documentation. Each student writes a daily log entry in personal logbook. Notes, data, some graded outputs are put in the logbook, as well. A daily log entry is required for every day of the course. The entry includes information about the activities performed that day and how much time each activity required. The entry states what the student will do the next day upon entering the class. Goals are established for daily routing, intermediate components of the course (e.g. The Final Design Report (FDR)) and the Project Goal. These goals are evaluated daily as to the percentage complete for each goal. Tracking of progress is accomplished by referring to the course Flow chart in every room. Finally, the Daily entry includes a discussion of factors that kept the student from being productive; e.g. group conflicts, daydreaming, off-task behavior of group members and school events. The evaluation of the logbook requires an entry for every day.

Laboratory Content:

Laboratory experiences are required with the SciTech course sequence. In the development of the GCP, groups carry out several labs. The purpose of the lab depends on the information needed for the application. The student can develop a specific lab for information needed by the group. But, there is information needed for the verification of the feasibility of any design. Every device must have enough energy to function. Our course is a true design course and not based on trial and error as other courses we observed in the authorship phase of course development. We believe you must prove a machine can do the challenge using math models and experimentation before you get to build it. We constantly offer up what it means to design versus developing prototypes using trial error.

With this in mind, the students need strong math modeling skills and they must be able to determine numbers through experimentation they then can use toward their design. The most substantial experimentation all students perform is the Mousetrap Energy Lab. We use mousetraps as energy sources for designs. To determine the energy available in a practical energy analysis, students must determine the exact amount of energy stored in a mousetrap. * We developed an energy analysis lab using Force versus Distance data with a graphical analysis to determine Slope and y-intercept. We teach a method using the "least squares fit" formula of data analysis to determine the best fit slope and y-intercept of line indicated by the Force and Distance data taken.

$$m = \frac{n\Sigma xy - \Sigma x \Sigma y}{n\Sigma x^2 - (\Sigma x)^2}$$

$$b = \frac{\Sigma y \Sigma x^2 - \Sigma x \Sigma xy}{n\Sigma x^2 - (\Sigma x)^2}$$

Observe that the sum of various data includes all the data points in determining the best linear characteristics for the data points. "Least squares fit" takes all data points into consideration when determining the slope and y-intercept of a linear plot. In contrast, using just a two-point slope method in a linear plot could have inaccuracies associated with not considering all the data taken.

$$m = \frac{\Delta y}{\Delta x} = \frac{y_2 - y_1}{x_2 - x_1}$$

The lab is also an "area-under-the-curve" analysis, which introduces integration as an applied math function. With Force on the y-axis and Distance on the x-axis and linear plot determined by the slope and y-intercept, the energy in the mousetrap is represented by the area-under-the-curve for the 180-degree swing of the mousetrap. The experimental control procedure only allows data to be taken from 0-140-degrees and requires the students to extrapolate the coordinates of Force and Distance at the 180-degree position of the mousetrap arm. A practical use of extrapolation allows class discussion of accuracy of method and precise experimental design to achieve reasonable, useable information for design.

Measurement accuracy, measurement precision, conversion of measurement units, and how to use vernier's on measurement tools (students use a vernier caliper for accurate distance measurement) is applied in the data collection. The lab is created in and rendered for grading within the student's own network account using Microsoft Excel for spreadsheet functions and

Microsoft Word for the Full Lab write-up. No papers are transferred to the teacher, the teacher grades the spreadsheet and the final full lab write-up from the student account. Data is taken in lab groups but the write-up is an individual output because this lab happens before final groups are assigned. This lab is universally done to determine the nature of our energy source. As the design phase continues a group of designers might need to design an experiment that pertains to their design.

Equipment Required:

The documentation required, the laboratory experiences, and the construction requirements demand that we provide equipment. We use a networked computer lab with a computer for every student in combination with a classroom for every section of the course. We use standard equipment for physics classroom based on kinematics (scales, measurement devices, stopwatches, and various demonstration apparatus). We build devices in a technology area with band saws, belt sanders, drill presses, various hand tools, squares, planes, soldering tools, hot glue guns, clamps, metal fabrication shears, grinders and lathes. Most discussions of equipment lead to the ultimate problem where do I get it? Or, how much will it cost me? We used what was available. We acquired the rest through donations of discarded industry equipment. And took advantage of our district phasing out vocational programs within our district. Industrial machines in our district were going to be auctioned at “pennies on the dollar” or worse, chunked! We asked them not to liquidate the machines and we would take them. Now, close to 400 students a day are involved with those machines that would have cost an enormous amount to buy from a provider.

Recognitions and Awards:

The course has been presented in various teaching professional conferences and has been recognized by various organizations over the 12 year development. April 26-27, 1996, we presented the curricula model development at the Third Annual Texas SREB Conference in Corpus Christi, TX. We were invited to present to The National Consortium of Specialized Secondary Schools for Mathematics, Science and Technology Professional Conference in New York City at Stuyvesant High School in 1996. We presented at a Texas professional conference, Conference for the Advancement of Science Teaching (CAST) in 1997. We were recognized as Top Ten Quality Schools of Choice with SciTech being cited as innovative curricula. We presented SciTech to the Institute of Physical Science for Austin Independent School District (AISD) for in-service on innovative teaching strategies in 1997. Countless observations of course by industry professionals have resulted in verbal recognition of the curricula as exemplary.

In 1994, a group of researchers from Vermont were piloting a Teamwork skills assessment model and heard of our program from conference contact. They proposed testing our students for development of teamwork characteristics. The model is titled, *Assessing Teamwork Skills for the Workplace Readiness Prototype Models* for the Council of Chief State School Officers (CCSSO). They collected data on the course in the fall semester and reported back to us in the spring of 1995. Their conclusion was that our students had all scored in the 99^{th} percentile of teamwork workplace readiness. And of the 30 or so sites they had tested to that point, no other site had scored so high. They said they would have to change the model do to the extraordinary teamwork skills we were developing in our students.

Links to Educational Standards:

Texas initially used the Texas Assessment of Academic Skills (TAAS) objectives for validity analysis of curricula. The SciTech objectives match all requirements of TAAS as well as its successor, the Texas Assessment of Knowledge and Skills (TAKS). Since both TAAS and TAKS correspond to National Standards for education we assume national compliance. The specific correlation to TAKS would not fit in space provided. The course was submitted to Texas Education Agency as replacement for Texas' physical science course for 9th and 10th grades and was approved as an honors course in Texas.

Project 2061 authored by the American Association for the Advancement of Science (AAAS) lead to a project Texas for Authentic curriculum development. Our Curricula model is a derivative of the model proposed by Dr. Carol Steussy's Coordinated Thematic Science II Model. SciTech is a non-linear model with performance objectives arranged in a circular pattern. Each circle represents the project aspects of the course. The circles(i.e. projects) intersect spokes in the pattern. Each spoke represents a universal science skill required by TAKS and the national standards. The correlation of SciTech Objectives to TAKS occurs in the performance objectives written at the intersection of the circular project objectives and the "spoked" science skill objectives.

The curricula development process was written up in a masters thesis, *Amplifying Teacher Voice of Curricular Reform in Science Education: Three enabling Characteristics of an Exemplary Teacher Workplace* by Melissa LeBoeuf Tothero MA at the University of Texas 1995 Supervisor: James P. Barufauldi. The Thesis develops the characteristics required in a public school setting to develop authentic curricula.

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